An Extragalactic Point Source Simulator for SIRTF Pipeline Testing

Sonali Kolhatkar, Fan Fang, Mehrdad Moshir

SIRTF Science Center, California Institute of Technology, Pasadena

1. ABSTRACT

We designed and developed a package which simulates extragalactic point source data within a given field of view and SIRTF band. Our method uses input empirical relations, such as known luminosity functions and galaxy spectral energy distribution templates. It also uses instrument filter information to produce a list of sources, their redshifts, positions, and fluxes. The output fluxes in the specified band are based on the user-specified luminosity and redshift evolution modes. We designed the simulator so that the empirical input and filter information can be easily modified. The simulator is modular and extensible to enable multi-wavelength simulations and has been optimized for speed by utilizing parallel processing capabilities. We have applied the extragalactic simulator using SIRTF instrument filters to test pipeline design.

2. DESIGN

The extragalactic simulator has a modular, linear design and consists of 6 stand-alone modules written in C. There are several additional input tables of data and parameters which are bound to the modules via a single C-shell script. The design of the simulator is well-suited to future extensions and modifications. The six modules are represented in Figure 1 as red boxes. Each module can be run alone at the command line for testing and debugging purposes. Each module also produces individual output and log files. All user-specific parameters reside in a separate file which can be easily modified. All other input data such as SED templates, filter responsivities, etc, can be replaced as more reliable and accurate information becomes available.

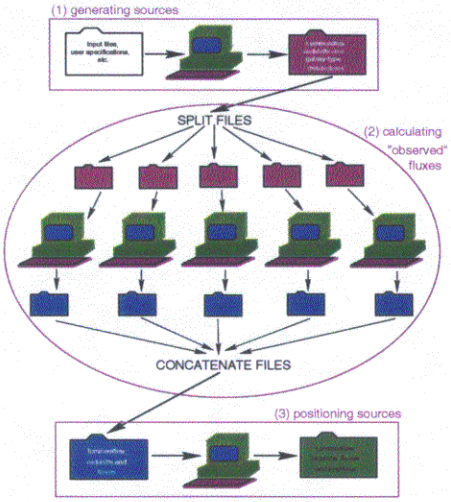

Figure 2. A C shell script runs the various modules to perform simulations. The most time consuming part is the calculation of fluxes. The script is designed to split the flux calculation process across several machines in order to optimize speed.

The simulator has been streamlined for high-speed processing and is capable of generating tens of thousands of extragalactic sources in minutes. This is enabled by splitting the most time consuming process over several processors (maximum of 20) and running them in parallel. Users can simply list available machines and run processes in the background of each machine. Figure 2 is a schematic representation of the parallel processing concept in the simulator design.

3. ALGORITHM

In the first stage of the simulator, we generate extragalactic sources for a given set of input parameters. This involves calculating the number of sources that falls within a user-specified area on the sky and simulating a set of basic attributes for each source. These attributes are: intrinsic and apparent luminosities, redshifts, and galaxy types (see part (1) of Figure 1). Intrinsic luminosities are based on a chosen "luminosity function" at a wavelength closest to that of the SIRTF filter for which the simulation is performed. The redshifts of the galaxies are calculated separately and based on a $(1+z)^{-\beta}$ power law model for co-moving density evolution from which redshifts are generated according to a scaled distribution, and randomly assigned to galaxies. Galaxy type assignments are based on intrinsic luminosities and SIRTF band wavelength. They comprise linear combinations of "Photo-dissociation Region (PDR)", "Star Burst (SB)" and "Active Galactic Nucleus (AGN)" types, determined by empirical data.

Using available Spectral Energy Distribution (SED) templates for PDR, SB, and AGN galaxy types, we construct individual composite SEDs in the second stage of the simulator (see part (2) of Figure 1). These are based upon the proportions of types calculated in the previous stage. For example, if a galaxy was a combination of 75% PDR, 20% SB and 5% AGN, it's SED would be a linear composite of PDR, SB, and AGN templates in the same proportions. Using the filter responsivity function of the specified SIRTF filter, we calculate the "integrated luminosity" of the galaxies by integrating the filter function with the normalized SEDs. We then determine fluxes according to the following relation: $Flux = L_{int}/4\pi D^2$ where L_{int} is the integrated luminosty, and D is the luminosity-distance of the galaxy.

The last step in the extra galactic simulator is to position the galaxies on the 2-dimensional sky (see part (3) of Figure 1). The correlated positions of galaxies are calculated according to a dumb-bell model of fractal structure (Soneira & Peebles, Astronomical Journal, 1978). A final output of the simulator contains extragalactic sources with corresponding luminosities, redshifts, fluxes, and positions in Right Ascension and Declination.

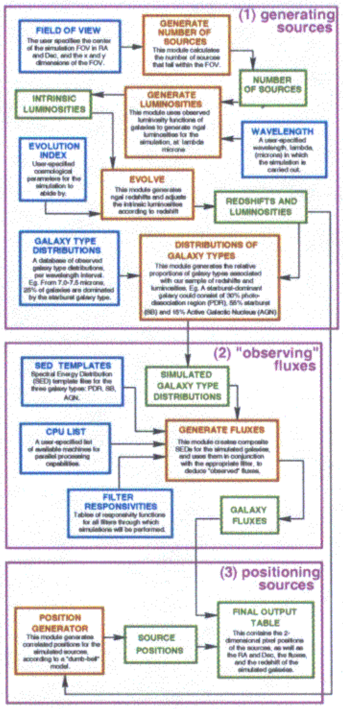

Figure 1. A schematic representation of the extragalactic simulator, split into its three main stages. Blue boxes represent input data, red boxes represent the modules which process the data, and green boxes describe the output.

4. RESULTS

The extragalactic simulator was implemented at four of the SIRTF filters on the IRAC instrument: 3.6 μm, 4.5 μm, 5.8 μm, and 8.0 μm. The table look-up method used to generate the luminosities of the simulated galaxies works well at all four wavelengths(see Figure 3 below).

A well-used test of cosmological models of the universe is the distribution of number counts of extragalactic sources (N) at different flux levels (S). An effective test requires a complete sample of galaxies out to relatively high redshifts. Figure 4 is a plot of $logN$ versus $logS$ for 34557 simulated extra-galactic sources within a redshift range of z=0 to 10. The SIRTF filter used here is the IRAC 8.0μm. The extragalactic simulator probes galaxies out to fluxes that are faint enough to be consistent with the micro-Jansky level sensitivities of SIRTF instrument filters.

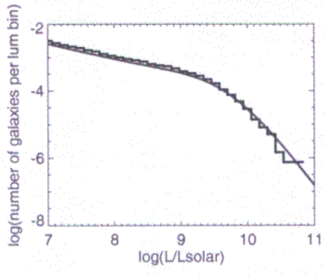

Figure 3. The number distribution of simulated luminosities generated at 8 microns. The overlaid smooth line is the 12 micron luminosity function from which the luminosities are drawn.

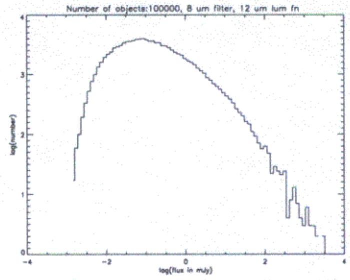

Figure 4. A logarithmic plot of the number counts of extragalactic sources binned according to flux. (this figure will be replaced by a more accurate one by the end of the week.

5. FURTHER TESTING

The extragalactic simulator is is capable of generating large numbers of galaxies within a given patch of sky for purposes of SIRTF pipeline testing. While tens of thousands of galaxies can be simulated within minutes, further techniques to speed up the process are under consideration. This includes "table look-up" methods in the flux calculation module which could theoretically replace individual calculation of fluxes. When available, luminosity functions can be replaced by newer ones recorded at wavelengths close to SIRTF instrument wavelengths. SED templates can also be replaced by newer, more accurate ones when available. In order to represent the full range of objects in the sky, this simulator will work in conjunction with a galactic simulator in the future (the SKY model, Cohen, M. Astronomical Journal, 1993), to produce data sets that contain external galaxies as well as objects within our own Galaxy.